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SALINITY - AN OLD ENVIRONMENTAL PROBLEM

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In Australia, problems of high salinity have been associated generally with irrigation of soils in semi-arid areas. However, excessive salt content of soils in the much more extensive areas of non-irrigated agricultural land has become significant within the last 50 years, as the ability to clear vast areas of land followed the development of mechanical fanning equipment. As the water resources of the continent have been exploited, the increasing demand, particularly since the 1940s, has highlighted the progressive degradation of rivers in many areas. The best known example is the River Murray, though others include the Blackwood River and Murray River in Western Australia, and the Glenelg River in south-western Victoria.

TERMS USED IN SALINITY

Salinity

Salinity describes the content of salts in soil, or in water. The most common chemical components are sodium, chloride, calcium, magnesium, potassium, bicarbonate and sulphate. The first two components dominate in most of Australia, accounting for 50 to 80 per cent of total salt content.

The salinity of water refers to the content of salts (as milligrams per litre, mg/L) dissolved in the water, usually termed the total soluble salts (TSS). This reflects the method of measurement by summation of the individual ionic components.

The salinity of soil refers to the content of soluble salts contained in the soil, and may be expressed as a percentage by weight of dry soil.

Saline soil

A saline soil contains sufficient soluble salts to reduce or eliminate plant growth.

Soil or water salinisation

Soil or water salinisation is the process of salt accumulation in the soil or water to the extent of adversely affecting the use of the soil for plant growth, or the water for supply to humans, stock, or industry.

The salt content of water affects its electrical conductivity (EC), allowing a simple measurement to

be made which is correlated with the TSS content in mg/L.

EC Units

Many water agencies use the term EC Units. This involves a measurement of the electrical conductivity of the water from which salinity is estimated. A commonly adopted relationship is

TSS -- 0.65 EC units

where an EC unit is one milli Siemen/centimetre.

Primary salinity

In Australia, there are areas with naturally saline water or soils in which the salinity levels have always restricted the range of possible uses. This is called primary salinity. They include salt marshes, salt flats and salt lakes, some in coastal regions, others well inland in semi-arid or arid regions. All are associated with highly saline groundwaters and often internal drainage. The estimated area of this type is 14 million hectares (ha). A further 15 million hectares of land in arid and semi-arid regions have naturally saline sub-soils, but no groundwater in the profile. If the vegetation is removed, the salt may be redistributed to the soil surface.

Secondary salinity

Human activities have resulted in adverse changes in the salinity of soils or waters. This is called secondary salinity, and is the type which is the subject of this article. There are two types of secondary salinity depending on the absence or inclusion of a groundwater system in the development and maintenance of salinity. The former type is usually found in the low rainfall pastoral regions of the middle latitudes of Australia. When excessive grazing causes soil erosion, the saline or sodic subsoils are exposed. The high sodium content assists the dispersion of the exposed subsoil to form a thin crust which substantially reduces infiltration of rain water. These areas remain devoid of vegetation, although there is no evidence of significant salt content in the water which runs off during rainfall. These areas are described as **scalds**. They are not associated with a groundwater system nor do they contribute to stream salinity.

Saline seeps

The secondary salinity problems in which groundwater is a key component have an impact on soil, vegetation and water resources. The salinity develops as the result of discharge of groundwater. In irrigated areas these saline soils are frequently termed scalds, but in non-irrigated lands the salt affected areas are called **saline seeps**. A saline seep is an area where salts accumulate at the soil surface as a consequence of the groundwater discharge from a confined or unconfined aquifer.

Excessive soil salinity creates an osmotic effect which makes it more difficult for plants to absorb water from the soil. Excessive salt content of the solution taken up from the soil may also have a toxic effect on the plant.

Soil surveyors have put 0.2 per cent salt content (by weight) as the upper limit for surface soils and 0.3 per cent for subsoils. Water salinity has a recommended upper limit for human consumption of 500 mg/L (TSS), though a salt content up to 1,500 mg/L (TSS) is acceptable, but some medical problems could be expected. Some authorities set upper limits for sodium content since excessive intake may contribute to hypertension. Guidelines for acceptable salinity of water for farm animals show variation depending on animal type and condition. Whereas 2,000 mg/L is the recommended maximum for poultry, dry sheep can maintain condition even at a salinity of 13,000 mg/L provided magnesium content is low.

EXTENT OF SECONDARY SALINITY OF SOIL AND WATER

A summary of the extent of current human-induced salinity of soil and water is given in the table below.

THE EXTENT OF HUMAN-INDUCED LAND AND WATER SALINITY IN AUSTRALIA

	Area of secondary salinised soils					
	Scalds	**Saline seeps (non-irrigated)**	**Irrigated Saline Soil**	**Area of shallow groundwater(>2m) in irrigated lands**	**Divertible surface water resources with >I~OO mg/L TSS**	
State	**'000 ha**	**'000 ha**	**'000 ha**	**'000 ha**	**mil. m3/year**	**% of total**
New South Wales	920	14	10	260	0	0
Victoria	60	100	144	385	220	2
Queensland	580	8	1	0.5	0	0
South Australia	1,200	225	0.5	4.5	82	(a)21
Western Australia	340	443	0.5	0	1,024	9
Tasmania	0	8	0	0	0	0
Northern Territory	680	0	0	0	0	0
Total	**3,780**	**798**	**156**	**650**	**1,326**	**1**

(a) Excludes imported water resources via River Murray.

Soil

The major areas of non-irrigated saline soils are in the southern half of the continent, and have an associated impact on the surface water resources. Frequently, the best agricultural land in the valleys is where the saline soils develop. The scalds are located primarily in regions receiving less than 400 mm rainfall per year where grazing of natural vegetation is the dominant agricultural practice. The Murray-Darling Basin supports 75 per cent of Australia's irrigated lands, with the consequence that New South Wales and Victoria contain 99 per cent of the area of saline irrigated soils.

Surface water

Excessive salinity of major divertible water resources in Victoria is found in streams along the south-western coast, and in the Avoca River. Rivers along the Millicent Coast and the Broughton River account for over 80 per cent of the salinised surface water resources in South Australia. In the south-western region of Western Australia brackish and saline waters are 36 per cent of the total divertible resource. The affected streams occur where rainfall is less than 900 mm/year and extensive land clearing has taken place. A further 865 million cubic metres per year (m3/year) of Australia's surface water resources are in the marginal quality category (between 500 and 1,500 mg/L TSS) located primarily in the same river basins mentioned above.

Groundwater

The extent of salinity in the major groundwater resources in Australia is given in the following table. There is very limited information on the volume of these groundwater resources which have been degraded since European settlement. The major impact appears to be associated with over

exploitation for irrigation or industrial use, resulting in salt water intrusion into previously good quality aquifers.

THE EXTENT OF SALINITY IN MAJOR GROUNDWATER RESOURCES IN AUSTRALIA

Divertible groundwater resources with >1,500 mg/L TSS

State	Surficial aquifers	Sedimentary aquifers	Fractured rock aquifers	Percentage of total resource
	- mil. m3 per year -			%
New South Wales	165	570	0	34
Victoria	0	92	7	11
Queensland	320	43	36	14
South Australia	0	456	5	38
Western Australia	321	508	84	33
Tasmania	6	2	0	6
Northern Territory	2	51	0	1
Total	**814**	**1,722**	**132**	**19**

Source: 1985 Review of Australia's Water Resource and Use. AWRC (1987)

TREND IN SECONDARY SALINITY DEVELOPMENT

Soils

Dryland salinity is expanding at about 2 per cent per year in Victoria. The average rate of increase in area of salt-affected soil in the south-west of Western Australia has been 6,000 ha/yr in the past 35 years, and no declining trend has been observed in recent years. The estimated area of saline seeps in South Australia has increased by 170,000 ha since 1982, though part of this may be a consequence of better assessment methods being applied. Based on limited data, it was predicted in 1982 that the area of salt-affected non-irrigated land in Australia would be about 900,000 ha by the year 2000. At current trends this will be exceeded.

Shallow water tables

Without artificial drainage, the area of shallow groundwaters is expected to increase in irrigation areas and create conditions leading to increased soil salinity. Within the next 40 years, shallow water tables could underlie 70 to 80 per cent of the Murrumbidgee Irrigation Area, 40 per cent of the Shepparton Region, and 90 per cent of land in the Kerang region. This situation could leave 15 to 25 per cent of the land with salinity high enough to render the land totally unproductive. The extensive drainage program in South Australia's Riverland region has lowered water table levels sufficiently to prevent further increase in soil salinity.

Groundwater

There is a lag between agricultural development and the full expression of its impact on the groundwater system. The effect of clearing may continue to cause rising groundwater levels in the immediate future, and where lag times are tens of years the effect on soil, groundwater and stream salinity may only now be beginning to appear.

The frequency of occurrence of salt water intrusion problems in groundwaters is expected to increase with continuing development in coastal zones, though correct management of extraction will avoid problems. Continuing excessive exploitation of groundwaters in inland areas to meet

irrigation demands will lead to rising salinity. This issue will be encountered until the use is managed within the safe yield of the aquifer systems.

CAUSES OF SECONDARY SALINITY

There are three basic requirements for salt to become an environmental problem:

- a source of salt;
- a source of water in which the salt may be dissolved; and
- a mechanism by which the salt is redistributed to locations in the landscape where it can be damaging, including into rivers.

Over 200 years ago European settlers began the removal of the native vegetation (usually Eucalyptus species) for development of both dryland and irrigated agriculture, particularly cereal cropping, grazing of sheep and cattle, and horticulture. This clearing accelerated in the period since 1900. About 3 per cent of agriculturally developed lands are irrigated through government or privately managed water supply schemes.

The source of salt

Many Australian soils have always contained high quantities of salt stored in depths of 30 metres or more. Most of the agricultural soils are quite old in geological terms, with deeply weathered or thick alluvial deposits of clays under the cultivated zone. Soil surveys have shown that about 238 million hectares are classified as containing high quantities of salt. About 50 per cent of these soils have been developed for intensive agriculture. However, this identifies only the salt content of the soil layer which is usually considered to extend to about 1 metre depth below the land surface.

The total salt content for the whole profile to basement rock has been studied extensively in the south-west of the continent. There is a systematic increase in stored salt with decreasing rainfall, ranging from 200,000 kg/ha at about 1,000 mm/yr rainfall to 1 million kg/ha at 600 mm/yr rainfall. Slightly lower quantities of salt have been measured in the northern slopes of Victoria over a similar rainfall range. Approximately 75 per cent of this salt is stored in that pan of the profile which was unsaturated with water at the time of vegetation removal. For the deep sandy profiles of the Murray Mallee in South Australia, the unsaturated zone is quite low in stored salt to depths of about 30 metres compared to the groundwater zone below in which the majority of salt is contained.

This accumulation of salt may originate from several sources: the ocean via rainfall, weathering of soil and rock minerals, and marine deposition in earlier geological periods.

The input via rainfall has been measured at 300 kg/ha/year near the coast, about 30 kg/ha/year at 250 km inland, and about 15 kg/ha/year at greater than 600 km inland. The total salt input from rainfall to the 106 million hectares of the Murray-Darling Basin in 1974-75 was measured at about one million tonnes per year. The rate of release of salts due to weathering of soil and rock minerals undoubtedly varies greatly, but addition to the soil profile is believed to be less than one-hundredth of that brought in by rainfall. Using the present salt input data, the measured salt storage could have been accumulated during the last 60,000 years.

In irrigation areas, the salt stored in the soil is supplemented by salt brought in via the irrigation water applied. The application of 1 metre depth of water with a salt concentration of 500 mg/L TSS adds 5,000 kg of salt to each hectare of irrigated land.

These data identify the accumulations in recent geological times as the major source of salt. This

salt is located in both the unsaturated zone of the profile and also in the accumulated groundwater where concentrations as high as 20,000 mg/L TSS are not uncommon.

The source of water

The change from deep-rooted perennial plants to shallow-rooted annual crops and pastures produces a reduction in evapotranspiration and an increase in net precipitation, that is, an increase in the amount of rainfall actually reaching the soil surface. Removal of the native vegetation decreases the interception loss estimated at between 9 and 13 per cent of rainfall in experimental forested catchments in Western Australia. The overall result is an increase in the volume of water draining below the root zone of the agricultural plants, and a cessation of any withdrawal of water by plants from the groundwater during periods of low rainfall. Groundwater levels rise and, even if no change in the gradient of the water level occurs, there will be an increase in the volume of water moving towards discharge sites either at a seepage area, or directly into a stream, at a lower elevation in the landscape.

The initial effect is usually an increase in the quantity of groundwater moving into the stream so that the impact is dependent on the salinity of the groundwater nearest the stream. The clearing of the land also increases the amount of surface run-off, which, because of its low salt content, dilutes the additional salt added to the stream from groundwater. The table below gives examples of the increase in salt load of streams due to clearing within the catchments.

The source of water for mobilising salt in irrigated lands is the excess water applied during irrigation. It is recommended practice to apply excess water above plant needs to leach away the salt which would otherwise accumulate in the root zone. The ability to control the volume applied for leaching is difficult. Excess application is often compounded by management practices because the timing of water application is often determined by water supply rather than by plant demand for water.

EXAMPLES OF SALT LOAD INCREASE IN RIVERS FOLLOWING CLEARING FOR AGRICULTURE

River Catchment	**Factor by which saltload has increased**
Dale River (WA)	19
Collie River (East) (WA)	15
Axe Creek (Vic.)	10
Avoca River (Vic.)	10
Finniss River (SA)	8
Bremer River (SA)	6
Hughes Creek (Vic.)	4
North Para River (SA)	4

The mechanisms for redistributing salt

The salinity problem is a groundwater problem. This identifies the primary mechanism by which redistribution of salt occurs. Stored salt is dissolved by the water moving vertically and horizontally underground and transferred to places of lower elevation in the landscape. A saline seep is a zone of groundwater discharge. Often this discharge occurs directly into the bed of a stream.

The patterns of subsurface water movement in a landscape are complex, depending on the variations in porosity of soils and rocks, the existence of layers with different hydraulic properties, the distribution of the input of water from the land surface modified by plant type and density, and the relief of the landscape. The groundwater may occur as an unconfined aquifer in one part of the landscape leading into a confined aquifer further down-slope. Analysing this variability has been

aided significantly by computer modelling. though obtaining the data for parameters in the models is a challenge.

Thus it is often difficult to determine why a saline seep exists where it does. or where the major water input (recharge) areas are located. without carrying out a drilling program to examine the profile features and monitor the groundwater hydrology. The heterogeneous nature of the soil and weathered zone materials underground was ignored until about 10 years ago.

Despite the complexity, a number of important hydraulic factors have been established. Usually the groundwater conveying salt to seepage zones has to move through weathered rock material such as clay which has a resistance to the movement of the water. Frequently there is a two layered groundwater system. The shallow aquifer is usually the dominant source of water with the deeper aquifer the major source of salt discharging to the saline seeps and into streams.

Geophysical methods are being increasingly employed to identify the features which control the movement of water and salt. The location of saline seeps is often related to subsurface structural features. An example is an elevated basement rock which acts like a subsurface dam wall.

Irrigation areas are generally located in landscapes of low relief. The excess irrigation water develops a groundwater mound underneath the area from which the horizontal flow of groundwater has a low gradient. Consequently, drainage into regions outside the irrigated area are quite limited. If in the surrounding dryland agriculture lands there is some groundwater recharge due to the removal of native vegetation, the drainage of groundwater from the mound of water under the irrigation area can be further retarded.

GOVERNMENT ACTION

The concern for salinisation has been expressed in the establishment by State governments of committees to make a major investigation of the problems: firstly in Western Australia (early 1970s), then Victoria (1982), New South Wales (1987) and South Australia (1989). In a major policy statement in 1989, the Federal Government confirmed that salinity change in Australian agricultural landscapes was a large component in the degradation of the environment, and focused on the urgent need to halt and reverse the trends.

The River Murray and the country it drains has suffered enormous problems of salinity and associated land degradation for many decades. The River Murray Water Agreement (1914) has been the legislative vehicle for management of water quantity only. It was not until 1981 that water quality was included. An historic agreement in 1985 established the Murray-Darling Basin Ministerial Council with the task of promoting and coordinating effective management and planning for the Basin. The Council has already developed a major salinity and drainage strategy. The current salinity of the river is set as the quality baseline against which future changes will be gauged. Joint funding by the State governments of New South Wales, Victoria and South Australia, plus the Federal Government will implement new salt interception and land use management schemes. There has been agreement that future disposal of salt into the river must be offset by dilution or removal of salt sources elsewhere in the basin.

SALINITY MANAGEMENT

It would be virtually impossible to eliminate all the stored salt, therefore, salinity management strategies need to eliminate the source of water or modify the mechanism which redistributes the salt.

Engineering

The engineering solution uses pumps, wells and ditches to establish drainage systems. This has been the normal procedure to control salinity in irrigation areas in Australia. In some cases gravity drainage schemes have been possible. Final disposal is often by pumping the excess water either to remotely located evaporation basins for return to the river at high flow periods, or, if quality is satisfactory, back into the supply channel.

Large costs have been incurred for drainage schemes aimed at controlling and possibly reducing the salinity of the water of the River Murray passing into South Australia. Some are on-farm schemes managed by the owner with government control of effluent disposal. Major sources of saline groundwater flow to the river down stream of Echuca are intercepted and the water pumped to evaporation basins. Rather than use the river as both water supply and drainage ditch, a proposal for a pipeline to convey saline effluent to the ocean is currently the subject of a feasibility study.

The use of engineering methods for groundwater control in non-irrigated lands has been minimal because the economic costs are high. In some drainage studies maintenance problems have discourage further experimentation. A major problem is the difficulty of disposal of the saline (often above sea water concentration) effluent without associated stream degradation.

Reducing excess recharge

It is generally accepted that the long-term solution to the salinity problem is through prevention of excess groundwater recharge. The water which currently passes beyond the root zone needs to be fully used in plant production. Because the excess recharge occurs over a large part of the landscape, though at variable rates, an approach involving the whole landscape is essential.

In irrigation areas there have been numerous methods tried to reduce excess recharge. Uniformity in infiltration of water applied during irrigation is achieved through the use of laser controlled land forming and grading, and this also assists the removal of excess surface water. For heavy textured soils land levelling is estimated to reduce groundwater accessions by 30 per cent for perennial and 60 per cent for annual pastures. The timing of the irrigation is equally important and demand scheduling techniques have been established which use climatic, plant and soil characteristics to establish time and volume of water application,

For the non-irrigated landscape the amount of rainfall which causes the rising water tables has been found from mass balance studies to be less than 10 per cent of annual rainfall, and often about 5 per cent. Agronomic management through use of different cropping rotations and alternative species is the most promising approach to increasing water use. Subterranean clover pastures have been found to be poor users of water by virtue of a shallow root system. The use of deeper rooted crops and pastures, and elimination of any period of fallow, are recommended. Cultivation practices are being examined as some produce compaction of the soil below the cultivated layer which may restrict root penetration. Simulation studies have suggested that increasing plant rooting depth to between 1 and 2 metres would provide the additional water use required to control recharge. '

Although studies have been underway for many years, there is no recommended practical method which can demonstrate the reclamation of a saline soil or river. The very nature of the problem and potential solutions require long term field trials. However, many of the components which are expected to form part of the solution are reasonably well understood. Consequently, these have been used to develop 'best-bet options' for whole-of-landscape management. The involvement of land owners is a vital factor as economic and social issues will be as important as environmental issues in achieving a satisfactory reclamation strategy.

Stopping clearing in catchments

An obvious control option is to stop clearing land in catchments which have substantial flows of good quality water but show a. trend of increasing salinity. Legislation has been enacted in Western Australia which prohibits further clearing in five water supply catchments. The opening up of new farm land in the Glenelg River (Vic.) basin did not proceed in the 1960s because it was shown that salinity of the Rocklands Reservoir would increase to unacceptable levels.

Reforestation

Reforestation has received considerable support as the primary means of controlling non-irrigated salinity. The earliest work involved planting of trees immediately upslope of the saline seep, anticipating that the trees would act as biological drainage pumps. This has not achieved the success hoped for, although there has been some lowering of groundwater levels. The Water Authority in Western Australia has used a strategy of tree planting in discharge areas to reduce the quantity of saline water seeping into streams. The lowering of groundwater levels by less than 1 metre over several years has occurred, but there has been an associated reduction in surface run-off which has affected the net salt concentration of stream flow.

There is no doubt that more trees are needed in rural landscapes. but they will be only part of the answer for economically reducing the cause of salinity. Tree plantations of varying densities have been established both for experimental purposes and by private land owners. It has been found that the impact on reducing groundwater levels is related to the percentage of the landscape reforested. The location and area of reforestation will probably be determined by knowing where the major recharge areas occur in a landscape. Scientists are placing this issue high on the priority list for research.

Agroforestry

Combining crops and pastures with strips of trees, the agroforestry approach. has considerable appeal because it appears to include the most favourable economic benefit. Considerable knowledge has been gained in the cultural practices required to establish and maintain a viable agroforestry system including aspects such as the amount of damage to trees by stock, the effect of certain tree species in suppressing growth of grasses adjacent to the trees, and the spacing between rows of trees. A new industry of tree farming has emerged in agricultural areas where there is a demand for pulpwood.

Salt land can be used

While efforts have been made to develop strategies to control dryland salinity the management of the saline areas to obtain some economic return from otherwise waste land has been successful. The grazing potential of salt tolerant species and the grazing management procedures for a sustainable saltland pasture have been established particularly in Western Australia. It has been found that water loss from vegetated saline areas is considerably better than from bare saline soil.

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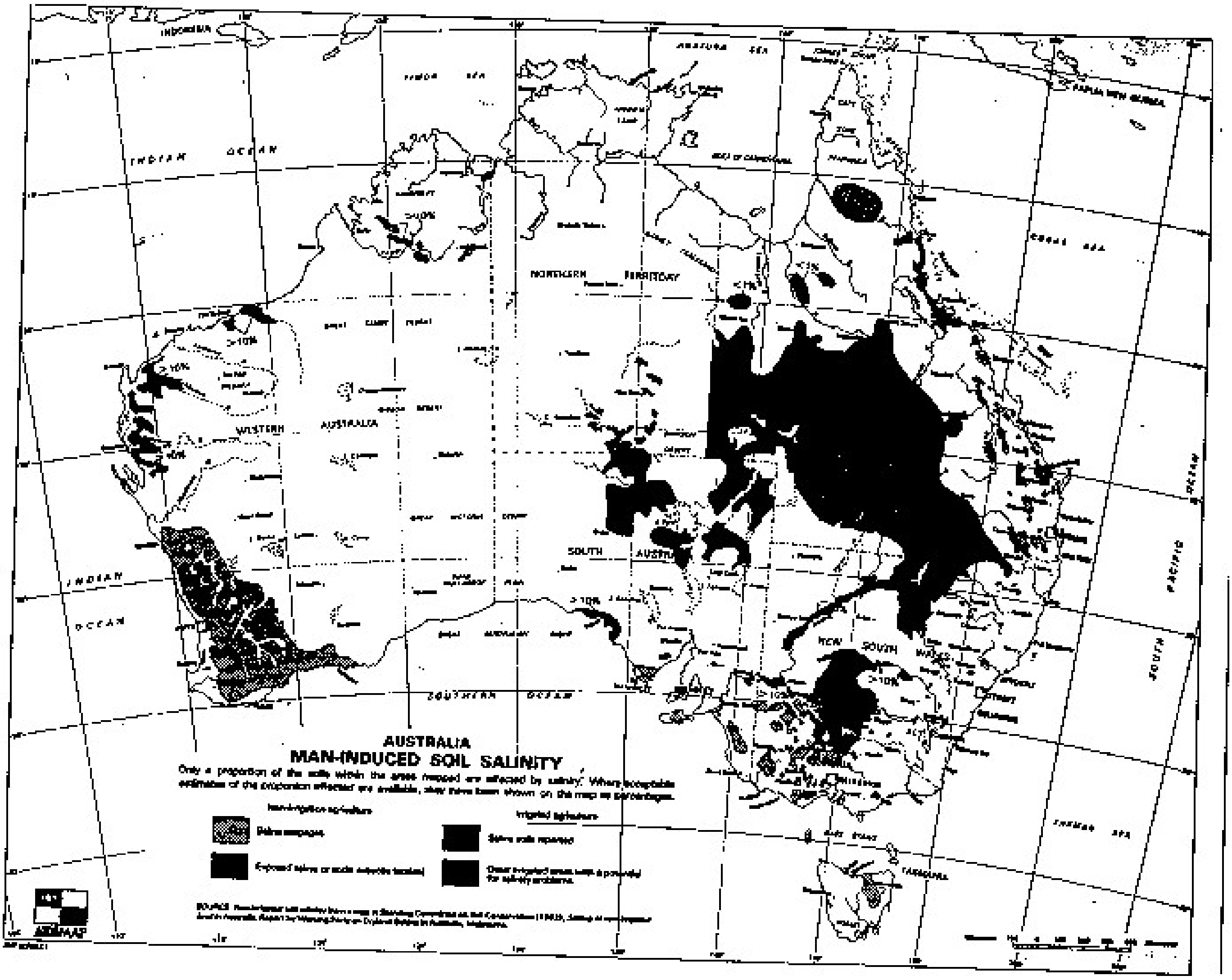

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